EXAMINING THE IMPACTS OF BRIDGING AND ADAPTIVE CO-MANAGEMENT STRATEGIES ON INVASIVE SPECIES MANAGEMENT

A Thesis

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by

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ABSTRACT

Invasive species are a pressing concern for biodiversity around the world. The emerald ash borer is an invasive species that causes ecological, economic and social impacts falling heavily on local governments and homeowners. My thesis utilized mixed methods to examine how engaging stakeholders in different levels of government (municipal, county and state), private sector firms, and researchers in local task forces enabled shared learning and facilitated invasive species management. Using adaptive co-management theory, I constructed case studies of learning, linking and connections to management based on surveys and interviews with members of three emerald ash borer task forces in New York. In light of literature on bridging organizations, I examined how the extension system in New York worked to bridge stakeholders to respond to EAB. Key findings included the role of knowledge networks in enabling local task forces to use ACM, network formation, and types of learning needed for invasive species management. Leadership emerged as a key theme. Further study is needed to clarify the potential of extension systems to provide bridging leadership across multiple resource issues.

BIOGRAPHICAL SKETCH

Sally Whisler Nourani was raised in Raleigh, North Carolina. Throughout childhood, she spent time playing in the woods and creeks of her neighborhood and took countless camping trips in the mountains of North Carolina with family. This early time outdoors shaped her interests and led her to employment during high school with Raleigh City Parks and during college with North Carolina State Parks. Throughout her time as a student at the University of North Carolina at Chapel Hill, she worked as a field research assistant, hiking around and standing in rivers collecting hydrology and geomorphology data in field sites all over North Carolina and in the Adirondacks, NY. She received a Research Experiences for Undergraduates grant from the NSF and carried out an undergraduate honors thesis project on the impacts of highly variable water levels from recreational dam releases on riparian plant communities on the Indian River, NY. She graduated with honors in 2008 with BA degrees in biology and environmental studies.

Following graduation, she was hired by RTI International worked on contracts for the EPA and private firms analyzing data on water quality and water supply security. While working at RTI, Sally began to volunteer with a neighborhood-based educational program for middle school students called the Junior Youth Spiritual Empowerment Program (JYSEP). After volunteering for two years, she left RTI International to take a full time position as a program coordinator for the JYSEP. In this role, she worked to improve the quality of the program by facilitating learning processes among volunteers.

In 2012 she moved to Ithaca with her husband and began to work for the Cornell Department of Natural Resources on research and extension programming for invasive species management.

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I would like to thank my parents, especially my dad, who made many trips from North Carolina to Ithaca to help me finish this thesis by providing childcare, nourishment and encouragement. I will be forever in debt to my dear friend, Alba Sancho, for taking care of my older son as I was starting this program and providing encouragement and more childcare when my energy flagged. Last but certainly not least, I'd like to thank my husband, Vesall, and my sons, Faizi and Monib for their support and sacrifices that as I completed this degree.

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Chapter 1: Introduction

INTRODUCTION

Invasive species are impacting biodiversity in marine and terrestrial ecosystems around the world. Defined as species whose introduction or spread outside their natural distribution threatens biological diversity, invasive species can occur in all taxonomic groups (CBD, 2000). Also called biological invasions and biotic exchanges, invasive species have particularly significant local and regional impacts, and cumulative global impacts (Sala, Chapin, Armesto, Berlow, & Leemans, 2000). They originate at a global level, often as a by-product of globalized trade. Preventative policies are put in place at national levels (Cook, Liu, Murphy, & Lonsdale, 2010). However, management tools available to remove or control invasive species are often highly localized and the spread of invasive species across the landscape is unpredictable and in some cases, rapid (Maguire, 2004). Eradication or control of invasive species often demands actions that span jurisdictions and property boundaries, and action or in-action in one place affects the outcomes elsewhere; therefore coordinated management is required (Epanchin-Niell & Hastings, 2010). Decisions about invasive species management tend to be complex with competing priorities and multiple stakeholder groups (Donlan & Martin, 2004).

A gap between invasion research and invasive species management activities has been observed (Bayliss, Wilcox, Stewart, & Randall, 2012; Esler & Prozesky, 2010). Although research and publications on invasive species have increased, managers who deal with invasive species are more likely to rely on their own experience and on non-academic websites than on published research (Lavoie & Brisson, 2015). This has been seen to result in mismatches between manager risk perceptions and quantified ecological risks of invasive species (Gozlan, Burnard, Andreou,

& Britton, 2013). The social, economic and political context of invasive species management is also important to managers and under-addressed in research (Matzek, Covino, Funk, & Saunders, 2014). Strategies that enable different stakeholders to communicate, integrate knowledge and learn together are needed.

Adaptive co-management is an approach that advocates for collaboration and learning in support of environmental management (Armitage, 2007). Adaptive co-management (ACM) is defined as 'forging links (both horizontal and vertical) for shared learning-by-doing between various actors, over a medium to long time horizon' (Plummer et al., 2012: 11). ACM brings together the linking aspect of co-management and the learning aspect of adaptive management with an explicit focus on the adaptability of the joint management process (Armitage, 2007; Bodin & Crona, 2009). The linking concept in co-management originated as a form of power sharing between government and local users where strong vertical linkages are formed from higher levels of government to local user groups. These agencies, firms and individuals each have particular knowledge as a result of their own position in relation to the resource and the society (Cash & Moser, 2000). Through a co-management process, these actors deliberate, each contributing the knowledge they have, creating a knowledge partnership (Berkes, 2009).

Success in co-management arrangements relies on not only the exchange of knowledge between partners, but the generation of new knowledge about the human-ecological system (Berkes, 2009). ACM expands the concept of co-management to include the learning-by-doing concept of adaptive management (Armitage, 2007). Adaptive management can enable stakeholders to overcome uncertainty and complexity in managing human-nature interactions by posing management actions as experiments, monitoring the outcomes, and utilizing the information gained to improve management (Holling, 1978). It has been used in the context of invasive

species management for the detection of new invasive species (Cook et al., 2010), to address information gaps at the beginning of management programs and assess the effectiveness of particular management strategies (Buckley, 2008), and as a component of wildlife conservation (Lyons, Runge, & Kendell, 2008). However, implementation of adaptive management has proved challenging. It requires a certain level of capacity on the part of managers, and may not be necessary or appropriate in all situations (Gregory, Ohlson, & Arvai, 2016). Co-management arrangements may enable participants to build their capacity for adaptive management over time (Berkes, 2009). Types of learning apart from adaptive management are important in ACM and come from varied theoretical roots (Armitage, Marschke, & Plummer, 2008). Baird et al. (2014) developed a framework for learning in ACM where learning is categorized into cognitive, normative and relational.

Using ACM to respond to invasive species impacts is promising; however, local and regional governments dealing with invasive species may not be equipped to initiate multi-stakeholder learning processes. Bridging organizations provide certain common services that allow an ACM process to begin including networking, building of a common vision and shared goals, research translation, trust building and co-production of knowledge (Berkes, 2009). By convening task forces or working groups of managers, private citizens, business people and researchers around a particular topic, bridging organizations reduce the cost of collaboration for the participants involved (Crona & Parker, 2012; Hahn, Olsson, Folke, & Johansson, 2006). The bridging organization itself becomes a powerful central actor in networks that cross levels of government and sectors of society (Hahn et al., 2006). Examples of this type of bridging occur in water management (Crona & Parker, 2012), air quality control (Stubbs & Lemon, 2001), urban ecosystem renewal (Ernstson, Barthel, Andersson, & Borgström, 2010), and wildlife

management (Raik, Lauber, Decker, & Brown, 2005; Schusler, Decker, & Pfeffer, 2003). Different organizations can play this role including municipal offices (Olsson, Folke, Galaz, Hahn, & Schultz, 2007) and university outreach and research translation offices (Crona & Parker, 2012).

THESIS OBJECTIVES

The goal of this thesis is to examine collaborative approaches to invasive species management within the context of the emerald ash borer (EAB) invasion in New York. The emerald ash borer (*Agrilus planipenis)* is an invasive beetle, first found in the US in Michigan in 2002, that causes widespread death of ash trees (*Fraxinus*). Detection of EAB is extremely difficult until populations have grown to the point of tree mortality. Once trees begin to succumb, the numbers of EAB in an area increase resulting in complete mortality of all ash trees in 10 to 15 years (Herms & McCullough, 2014). Dead and dying ash trees pose a public safety hazard if they are near houses, along roads and in parks. Removal of these trees can be expensive and the financial burden falls heavily on local governments and homeowners (Aukema et al., 2011). As a strategy to assist county and municipal governments and other stakeholders prepare and respond to the impacts of EAB, staff from the Department of Natural Resources (DNR) at Cornell University initiated a program to form collaborative groups called EAB community task forces. EAB task forces included state and county agency personnel, municipal representatives, professional land managers, landscape and tree-care companies, pesticide distribution firms, environmental organizations, and citizen volunteers (Whitmore, Hargrave, & Nourani, 2012). The objective of this thesis is to analyze the impact of these task forces on EAB and ash management using two related theoretical frameworks, ACM and bridging organizations.

In Chapter 2, I examine the potential use of adaptive co-management for invasive species. Case studies of potential ACM have multiplied in many resource contexts: forestry, fisheries, lakes and rivers, wildlife and protected areas (summarized in Plummer et al., 2012). Adaptive management has been used with invasive species (Buckley, 2008; Cook et al., 2010; Lyons et al., 2008). Co-management can also be used to address invasive species through bringing resource managers and resource users in contact with a plurality of knowledge (McClenachan, O'Connor, & Reynolds, 2015). I suggest in this chapter that based on the characteristics of invasive species discussed above, local communities may benefit from ACM when dealing with a new invasion. I conceptualized ACM by viewing linking and learning as functions that could be promoted through an intervention. To better understand how linking and learning may assist with invasive species management, I conducted case studies of three EAB task forces. I constructed the case studies based on an online survey of task force participants (n=69) and 12 in-depth interviews. I used social network analysis tools to examine changes in the networks within each task force and analyzed learning along three typologies: cognitive (new information), normative (changes in goals/views), and relational (new communication or collaboration) (Baird, Plummer, Haug, & Huitema, 2014; Plummer, Shultz, Armitage, Bodin, & Crona, 2014). In order to connect the intervention to outcomes, I then collected information on ash management plans, tree removals and treatments that had been conducted by municipal and county agencies. Findings revealed evidence of cognitive, normative and relational learning and network formation, meaning task force members made connections with individuals they were not previously connected to. Differences among the cases emerged in the connections to outcomes: in two cases the task force was largely used for exchanging information, whereas in the third prior collaboration enabled co-management and learning-in-action to occur. This chapter advances the ACM literature by

looking at how ACM can be used in the context of invasive species and by highlighting differences in community capacity that may impact outcomes. This chapter is being prepared as a manuscript for submission to *Ecology and Society.*

In Chapter 3, I discuss the potential of extension systems to contribute to environmental governance by creating opportunities for bridging. Leadership and civic engagement have a long history in extension; additionally extension personnel are neither state nor private actors, positioning them to create neutral ground for collaboration (Wilson, 1940). In this paper, I reviewed literature on bridging that highlights the potential for knowledge gathered at different spatial and jurisdictional scales to be consolidated and used in management. Success in bridging initiatives has been linked to leadership that can attract participation and commitment from diverse participants and develop a shared vision of the issue and common objectives (McMullen & Adobor, 2011; Olsson et al., 2007). Bridging organizations reduce the cost of collaboration for all actors by convening meetings, facilitating communication, and bringing together different constellations of stakeholders based on the need of the moment (Crona & Parker, 2012; Folke, Hahn, Olsson, & Norberg, 2005). Bridging and bridging organizations potentially have a large contribution to make to continued learning in environmental governance through enabling information to be pooled and collective action to emerge in response to disturbances (Berkes, 2009; Ernstson et al., 2010). To understand and describe the role of extension at both the university and county levels in the formation of the EAB task forces, I used data collected for Chapter 2 as well as analysis of meeting minutes and participant observation. Findings include unique leadership provided by both university and county extension personnel that drew in a diverse set of actors to address EAB management, and enabled the development of a shared vision of the trajectory of the invasion, likely impacts and management options. Task force

meetings were used to pool information from many sources for the benefit of managers, and forms of collective action emerged. Based on this case, I argue that extension systems are positioned to facilitate bridging and contribute to environmental governance. A manuscript based on this chapter is being prepared for submission to the *Journal of Extension.*

STUDY LIMITATIONS

My initial involvement with the emerald ash borer task forces was as a staff member with Department of Natural Resources at Cornell University. I made visits to EAB task force meetings in 2012 and 2013, that allowed me to become familiar with the participants, their reasons for participating and the goals and objectives of the task forces. My continued contact with the task forces in 2014 and 2015 allowed me to observe processes unfolding that enabled or hindered them from meeting their objectives. I then moved into research on the EAB task forces for this thesis. Occupying multiple roles in the research setting can enrich the perspective of the researcher, but can also introduce certain biases or limitations into the research. I will discuss below the ways my position and research design choices impact my findings.

Through contact with the research setting and review of ACM literature, I began to conceptualize ACM as made up of two simultaneous, interconnected functions, linking and learning, that could be stimulated through an intervention, such as a task force. I adopted a multi-case case study approach to make comparisons between the task forces using a framework that analyzes ACM arrangements through examining four components (activities and practices associated with ACM, network analysis of people involved in the initiative, an assessment of learning, and connections of these three factors to outcomes) (cf. Plummer et al., 2014).

These choices frame my research and present certain limitations. I selected EAB task forces to include as case studies that met regularly (quarterly, semi-monthly or monthly), excluding several counties in New York where one or two task force meetings were organized but no subsequent meetings occurred. This research, therefore, does not address what causes task forces to work in some areas and not in others. ACM is explicitly instrumental, meaning that outcomes are desired. I chose to focus on ash management by counties and municipalities as a main outcome of interest as local governments are heavily impacted by EAB. Other outcomes, such as public awareness and ash management on private property, are important to the resource situation but not the focus of this study.

My dual role in the setting gave me access to task force participants and enabled me to "member check" my ideas through many informal conversations with individuals involved in the EAB task forces. I guarded against an overly optimistic view of connections between the EAB task forces and outcomes for ash management by collecting data on ash management for all municipalities in each county and then probing to understand the connection (or lack of connection) between the EAB task force and these management actions. By taking this approach, I could consider the outcomes in light of the overall situation of EAB and ash management in the county.

The characteristics of EAB and the Cornell Cooperative Extension System also heavily influenced the results of my research. The public safety hazards and catastrophic impacts associated with EAB drew attention and participation from a wide range of stakeholders, which might not happen with all invasive species. The nature of Cornell Cooperative Extension as the extension system in which I was working also influenced the findings. The reputation and connections of the Cornell Cooperative Extension System influenced its ability to act as a bridging organization. Not all extension systems are alike in this regard. Thus, this research

should be viewed as an initial exploration of ACM and the role of extension systems in facilitating bridging for invasive species management.

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Chapter 2: Linking and Learning for Invasive Species Management

ABSTRACT

The impacts of invasive species are a pressing concern for biodiversity around the world. Responding to invasive species requires communication of research, localized management, and collaboration across jurisdictional boundaries. In this study I examine the use of adaptive co-management to mitigate the impacts of emerald ash borer, a wood-boring beetle that causes widespread death of ash trees, by assessing learning along three typologies (cognitive, normative and relational), linking (through network analysis), and connections of learning and linking to management outcomes in three case studies set in New York. Findings indicate that knowledge networks are used and built through learning platforms, such as local task forces, which bring stakeholders together. In addition, this study suggests types of learning that are needed for stakeholders to respond to invasive species management.

INTRODUCTION

Invasive species are impacting biodiversity and habitat in marine and terrestrial ecosystems around the world. Defined as species whose introduction or spread outside their natural distribution threatens biological diversity, invasive species can occur in all taxonomic groups (CBD, 2000). Decisions about invasive species management tend to be complex with competing priorities and multiple stakeholder groups (Donlan & Martin, 2004). The tools available to remove or control invasive species are often highly localized and the spread of invasive species

across the landscape is unpredictable and in some cases, rapid (Maguire, 2004). Eradication or control of invasive species often demands actions that span jurisdictions and property boundaries, and action or inaction in one place affects the outcomes elsewhere; therefore coordinated management is required (Epanchin-Niell & Hastings, 2010). Although the impacts, stakeholder groups, and decisions around management vary based on the species, adaptive and collaborative approaches may aid in the eradication, control or mitigation of many invasive species.

Adaptive management has been used in the detection of new invasive species (Cook et al., 2010), to address information gaps at the beginning of invasive species management programs and assess the effectiveness of particular management strategies (Buckley, 2008), and addressing invasive species as a component of wildlife conservation (Lyons et al., 2008). In addition, a study of collaborative management of the soft-shelled clam fisheries in Maine impacted by a green crab invasion compared the capacity of state and non-state actors (McClenachan et al., 2015). However, we are not aware of studies examining combined adaptive and collaborative management for invasive species.

Adaptive co-management (ACM) combines the "learning function" of adaptive management and the "linking function" of co-management (Plummer et al., 2012). The generation of new ecological knowledge through "learning-by-doing" (adaptive management), and social or institutional learning (collaboration, joint decision making, and multi-stakeholder arrangements) are both necessary parts of ACM (Armitage et al., 2008). The linking function of ACM makes connections between stakeholders horizontally (among public, private, non-profit and academic sectors) and vertically among levels of government (Plummer et al., 2012).

In this study I investigated ACM in invasive species management in the context of the emerald ash borer (EAB), an invasive beetle originating in Asia causing the widespread mortality of multiple species of the genus *Fraxinus*, commonly known as ash trees, across North America and Russia, and moving rapidly toward Europe. EAB causes social and economic in addition to ecological problems. A 2011 economic analysis concluded that the financial impact of EAB was borne by homeowners and local governments, via local expenditures and losses to property value, not by the timber industry or on governments at other levels (Aukema et al., 2011). The impacts on public safety, liability and local expenditures from dead and dying trees result in a diverse group of stakeholders with different objectives. The pace of impacts is rapid; EAB causes 100% morality of all ash species within 10-20 years of introduction (Smitley, Davis, & Rebek, 2008). This relatively short time frame enables the observation of multiple aspects of management, including movement of information, decision-making, management planning and implementation, and the outcomes of management decisions. There is strong consensus about the nature of the ecological interactions and management options are fairly well known (McCullough & Mercader, 2012), suggesting that the object of adaptation or learning around EAB may not be the ecosystem dynamics, but rather the institutional structures needed to manage rapid decision-making at a local level.

To investigate the use of ACM for EAB management, I conducted case studies of three county-level task forces in New York State, USA, set up to assist governments, organizations and private citizens to prepare for and respond to EAB impacts. The overarching question I address is: how can learning and linking in a local task force facilitate management planning and action? The specific research questions are:

1. What types of learning are occurring in the task forces?

2. What impact have the task forces had on network formation among participants?
3. How have the task forces influenced municipal and county ash management?

LITERATURE REVIEW

Environmental crises, such as invasive species, can trigger social reorganization, providing an opportunity for new forms of collective action and social learning (Olsson, Folke, & Hahn, 2004; Ostrom, 2009). To integrate information held by different individuals, innovative arrangements are needed that cross scales and levels (Cash, Adger, & Berkes, 2006). In this section, I introduce knowledge-based issues in invasive species management, examine learning and linking as functions central to ACM, and recent advances for measuring these functions, and then highlight links between ACM and adaptive capacity.

The Invasive Species Knowing-Doing Gap

A gap has been identified between invasive species research and management (Esler & Prozesky, 2010; Matzek et al., 2014). When a new invasive species is discovered, research typically is undertaken on the processes underlying the invasion, the impacts of the invasive species, and the options for managing it (Kueffer & Hadorn, 2008). Although this research is published, managers who deal with invasive species are more likely to rely on their own experience and non-academic websites (Lavoie & Brisson, 2015). This gap results in mismatches between manager risk perceptions and quantified ecological risks of invasive species (Gozlan et al., 2013). Bayliss et al. (2012) identified two potential remedies: low cost and easily accessed publications and direct interaction between managers and researchers. Matzek et al. (2014) suggested that invasion biology research must include social science questions to address the

needs of managers. A key contribution of ACM initiatives in invasive species may be closing the gap between researchers and managers.

Learning

Learning is central to dealing with the complexity in natural resource management (Lee, 1999). Concepts of learning in ACM are diverse and come from multiple theoretical sources (Armitage et al., 2008). Adaptive management (Holling, 1978) is central to ACM and is promoted as means to deal with uncertainty, lack of information or tradeoffs. However, implementation has proved challenging. It requires a certain level of capacity on the part of managers, and may not be necessary or appropriate in all situations (Gregory et al., 2016). Social learning is another prominent concept in ACM (Plummer et al., 2012). Social learning entails interaction within social groups (Argyris, 1977; Haas, 2016), facilitates collective action and reflection to improve human-environment relations (Keen, Brown, & Rob, 2005), and requires that the new knowledge is not only retained in individuals but permeates their social groups or networks (Reed & Evely, 2010). Platforms that facilitate interaction among individuals, organizations, agencies and private firms can enable social learning despite differences in knowledge, modes of operation, and scales among participants (Keen et al., 2005). However, the ability of a group to engage in social learning is heavily influenced by interpersonal relationships and enabling or disabling policies and structures (Keen & Mahanty, 2005). Social learning can contribute to adaptiveness, or adaptive capacity, by catalyzing the production of new knowledge to respond to a disturbance, build consensus, and empower stakeholders to take adaptive actions (Lebel, Grothmann, & Siebenhu, 2010). Adaptive capacity is a term that describes the capacity of a social system to deal with change and disturbance by learning, sharing knowledge, and responding to feedbacks (Fabricius, Folke, Cundill, & Schultz, 2007; Olsson et al., 2004; Walker et al., 2002).

In this study, I consider types of learning that occur both at an individual and a social level to facilitate invasive species management. Individuals are the agents of learning and must gain and digest information in order to take action (transformative learning, cf. Armitage, Marschke, & Plummer, 2008). Interaction, inclusion and negotiation among stakeholders allow different types of knowledge to be pooled and utilized by the individuals (Plummer, FitzGibbon, & Armitage, 2007), and may enable changes in understanding in the social group as well (Reed & Evely, 2010). To translate management objectives into successful action, stakeholders may need to engage in learning-in-action, or experiential learning (c.f. Armitage et al., 2008b). Parsing who is learning and what is being learned is difficult as indicated by the critiques of learning and social learning in ACM (Armitage et al., 2008; Reed & Evely, 2010). A framework developed by Baird et al. (2014) clarifies types of learning that operate at both an individual and group level. Cognitive learning refers to the acquisition of new knowledge or modification of existing knowledge. Normative learning refers to changes in norms, values or paradigms, or a convergence of views. Relational learning implies increases in trust, cooperation and communication (Baird et al., 2014).

Linking and networks

Co-management describes a range of power-sharing arrangements between local communities and the government and has an extensive history in the literature and in practice in various parts of the world. Originally associated with legally mandated arrangements to resolve conflicts between government and user groups, the concept has moved forward to include other forms of linking between levels of government and public and private groups (Berkes, 2009). Co-management can enable managers and scientists to exchange perspectives and engage with different types of knowledge (Wollenberg & Iwan, 2007). Bridging organizations may be able to

catalyze ACM by deliberately building social networks that cross levels of government and sectors of society (Crona & Parker, 2012; Plummer et al., 2012).

Social networks in environmental management facilitate the generation and diffusion of different types of knowledge, the mobilization of resources, and the resolution of conflicts (summarized in Bodin & Crona, 2009). However, structural characteristics of social networks can facilitate or hinder collaborative management (Bodin, Crona, & Ernstson, 2006). The presence of dense social relations among actors in a network is thought to promote trust, reduce conflict, and facilitate collaboration and learning (Bodin et al., 2006; Plummer et al., 2014; Putnam, 2000). Diversity in a network is also thought to contribute to ACM as members bridge structural holes to other networks, providing access to additional sources of information (Burt, 2003; Plummer et al., 2014). Networks that cross scales and sectors increase adaptive capacity by facilitating knowledge sharing (Olsson et al., 2004; Pahl-Wostl, 2009). However, excessively high density of ties can produce homogenization within a network, stifling innovation and reducing the ability of actors to adapt to changing conditions (Bodin & Crona, 2009).

Measuring ACM

A recent review of 108 ACM studies revealed that a lack of consistent metrics for evaluating potential cases of ACM was hindering the development of generalized knowledge (Plummer et al., 2012). With the goal of contributing to the body of knowledge on the application of ACM, I adopted a framework for this research that suggests that a diagnostic approach can be taken towards potential cases of ACM by examining the following components: a) activities and practices that indicate ACM; b) learning and networks; and c) connections of these components

to outcomes (Plummer et al., 2014). Although other frameworks have been developed for ACM (Plummer et al., 2007), this is the most methodologically detailed that I found.

METHODS

Research Setting and Case Selection

This research was set in New York where the loss of ash will result in tens of thousands of dead and dying trees in urban areas and large dead patches in forests. Cornell University, in partnership with Cornell Cooperative Extension (CCE) and the New York State Department of Conservation, formed groups called EAB community task forces to assist county and municipal governments and other stakeholders prepare and respond to the impacts of EAB. Task force membership included state and county agency personnel, municipal representatives, land managers, professional arborists and tree-care companies, utility company personnel, and citizen volunteers. I coordinated communication among the EAB task forces prior to and during this investigation. This involvement provided me with breadth and depth of knowledge of the research setting and influenced the study design. Initial task force meetings took place in eight locations around New York. Subsequent meetings occurred in five locations around New York, representing a county or multi-county area. I chose three of these task forces to include as cases in this study based on two criteria: regular meetings for more than two years, and rural/urban diversity. I focused on task forces with regular meetings to observe the impacts of learning and linking over time among a group of stakeholders. To compare responses in urban and rural settings, I chose two EAB task forces working in urban or suburban counties and one working in a rural county.

Data Collection

This investigation adopts a multi-case case study approach (Yin, 2003) to explore the following theoretical proposition: an intervention, such as a task force, can lead to outcomes for invasive species management through two mechanisms: 1) stimulating learning among stakeholders about the invasive species and management options and 2) facilitating communication between stakeholders from multiple levels of government and sectors of society. The three cases (Table 2.1) represent a mixture of urban and rural settings and important differences in the intensity of EAB infestation. The county in Case 1 includes one small city (population of 23,000) and towns and villages, with large amounts of open forest. Cases 2 and 3 are of counties with a large city, surrounded by suburbs. EAB impacts were most advanced in Case 1, where EAB was discovered in 2010. Case 2 had no EAB infestation when the task force began, but a small infestation was discovered during the study period. Case 3 represents a middle between these extremes.

Table 2.1. Background Information on Case Study Locations.

	Case 1	Case 2	Case 3
Area of county (square miles)	1,161	806	1,227
Total population	180,998	468,387	919,866
Number of municipalities	27	35	42
Year EAB discovered in county	2010	2013	2011
Estimated size of infested area in 2015 (square miles)	1,218	121	1,110

To develop the case studies, I used a learning assessment and networks survey via Qualtrics (N= 67, 63% response rate overall, see Table 2.2 for response rate by case), in-depth interviews (N=12) (see Appendix 1 for survey instrument and interview guide), and document analysis. For the purpose of this study, individuals were considered to be a participant of a task force if they attended two or more meetings. To address the research question "What types of learning are

occurring in the task forces?" I adapted a survey instrument from Plummer et al. (2014) assessing three types of learning: cognitive, normative, and relational (Plummer et al., 2014).

To assess "What impact has the task force had on network formation among participants?", I used a survey instrument to collect social network data, asking task force members how frequently they were in contact with every other member prior to their involvement with the EAB task force (retrospectively) and within the last year, based on a list of names provided in the survey (Marsden, 1990). Task force members were also asked to independently identify up to 10 individuals or organizations they went to for information on EAB beyond the list of names provided using a recall approach (Marsden, 1990).

To assess, "How have the task forces influenced municipal and county ash management?" I used open-ended survey questions and meeting notes to gather information on ash management activities (tree inventories, management plans, tree removals, pesticide treatments) conducted by municipalities and counties. I then used semi-structured interviews to trace connections between the EAB task forces and these management activities. Interviewees were initially drawn from task force facilitators, who then suggested other task force members to interview. The goal of the interviews was to confirm and add to the information on municipal and county ash management and to trace what types of interactions those managers had with the EAB task force (i.e., participated in a workshop put on by the task force, participated in task force meetings). Probing questions were asked to uncover information about how attendance at a task force meeting influenced their management decisions (i.e., received information, proposed management actions and received feedback, collaborated on grant proposals). Interview data complemented the network data by adding descriptions and examples of the contact among task force members and of new connections made. I compiled meeting notes from each task force between the formation

of the task force (all formed in 2011) and the end of the study period (2015) in order to examine what types of information were exchanged or produced, expressions of shared goals or objectives, and joint activities that were undertaken.

Table 2.2. Survey Population, Response Rate to Web-based Survey and Number of Interviews by Case.

	Case 1	Case 2	Case 3
Number of Task Force Members	16	24	27
Response rate	50%	68%	70%
Number of interviews	5	3	3

Data analysis

I analyzed data from the learning assessment first by transforming the 5-point Likert scale (strongly disagree-1, strongly agree-5) to a three-point scale (disagree, neutral, agree), and then summarizing by case and by question, numbers of respondents who agree or disagree (Figure 2.1). Cognitive learning questions that addressed different aspects of EAB (biology, social impacts, economic impacts) were combined.

I analyzed the structure and formation of networks using the following measures: *density*, i.e., the number of links between members in each EAB task force out of the total possible number of links, and *degree centrality*, the number of links each individual has, going both to (in-degree) and from (out-degree) individuals in each task force (Hanneman & Riddle, 2005; Prell, 2011). The centrality measures in this study are underestimates of the entire network as a result of missing data. However, I elected to use in-degree centrality to characterize the whole network as it is more stable than other network metrics when using an incomplete data set; Costenbader and Valente (2003) used bootstrap sampling procedures to compare the effect of sampling on 11 different network metrics and demonstrated a high correlation (90%) between whole-network in-

degree centrality calculations and a 50% sample of the network. To compare pre and post networks, I regressed in-degree centrality against membership in any given case. I also used in-degree centrality to assess the number of task force members who named academic researchers as an individual they go to for information on EAB.

I used out-degree centrality to assess the formation of new contacts by task force members. Out-degree centrality refers to the number of connections each survey respondent indicates they had with every other respondent. The number of links each individual gave to other task force members prior to the task force was subtracted from the number of links each individual gave after the task force, revealing how many new connections they made. Density, degree centrality measures, and regressions were all calculated using R (McFarland, Solomon, Nowak, & Westwood, 2010). Network maps were produced in UCINET (Borgatti, Everett, & Freeman, 2002).

Interviews were transcribed using MechanicalTurk and then coded using NVivo. Information from the interviews, survey, and meeting notes on ash management, including inventories, management plans, tree removals, and insecticide treatments, were compiled, and used to identify municipalities in each county actively involved in ash management. The first author used causation coding (Saldana 2016) on data combined from meeting notes and interviews to uncover connections between participation in the task force (documented in meeting attendance records) and management. Descriptive codes were used on interview data to identify patterns on emergent relational outcomes, such as new partnerships and new cooperative undertakings to address EAB, and partnerships that may extend past the task force and be applicable on other issues. I coded meeting notes for research communication (expert presentations, distribution of publications and webinars), collective goal setting, joint actions, information on EAB

monitoring, and municipal and county ash management activities. The names of the counties, task forces, and members have been withheld at the request of study participants (IRB Protocol # 1303003715).

RESULTS

My results indicate multiple types of learning took place within the EAB task forces. Task force members reported new cognitive knowledge on EAB, greater understanding of the perspective of others, and enhanced communication and cooperation with others. Network data confirm that new links formed among task force members and that these links represent new contact between stakeholders from different levels of government, private firms, and non-profit organizations. Connections between the EAB task forces and ash management on public property were documented. However, the density of network connections, evidence of co-management activities, and the capacities within the task forces for learning-in-action emerged as key differences among the three cases.

Learning

I discuss the results from the learning assessment along each of the learning typologies: cognitive, normative and relational. Task force members reported cognitive learning through their involvement in the task force (Figure 2.3), namely increases in their understanding of the ecological, social and economic impacts and management options for EAB. When asked if the majority of their knowledge on EAB came from participating in the task force, responses were

Table 2.3. Survey respondents' self-assessment of learning. Neutral responses are not displayed.

Learning Type	Statement	Case 1 n=7		Case 2 n=14		Case 3 n=16	
		agree	disagree	agree	disagree	agree	disagree
Cognitive	...my understanding of ecological impacts increased	100%	0%	86%	0%	100%	0%
	… my understanding of social and economic impacts increased	100%	0%	93%	0%	100%	0%
	… my understanding of management options increased	100%	0%	71%	0%	94%	0%
	Majority of knowledge on EAB comes from task force involvement	71%	0%	71%	14%	56%	19%
Normative	…helped me understand the perspective of others	86%	0%	93%	0%	100%	0%
	...has changed my view on which goals should steer management	100%	0%	50%	36%	56%	13%
Relational	...has enhanced my cooperation with others that participate…	100%	0%	71%	7%	100%	0%
	...has enhanced my communication with others that participate…	86%	0%	79%	7%	100%	0%
	I have collaborated with individuals I have met other projects	100%	0%	86%	14%	69%	0%

mixed. This result is expected; some task force members came in with expertise on EAB whereas others used the task force as their main source of information.

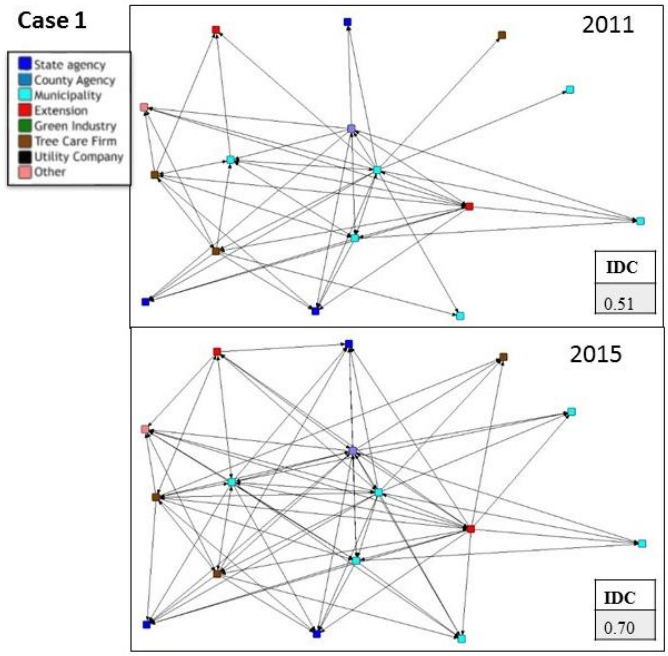
Task force members reported that participation in the task force increased their understanding of the perspectives of others, a characteristic of normative learning. When asked if involvement in

the EAB task force changed their perspectives on what goals should steer ash management, another aspect of normative learning, responses were mixed; the strongest agreement to this question was in Case 1 and the strongest disagreement was in Case 2.

Task force members reported increases in communication and cooperation with other task force members across all cases, indicators of relational learning. Case 1 and Case 3 had the highest levels of agreement, with some members of Case 2 disagreeing that the task force enhanced their communication and cooperation.

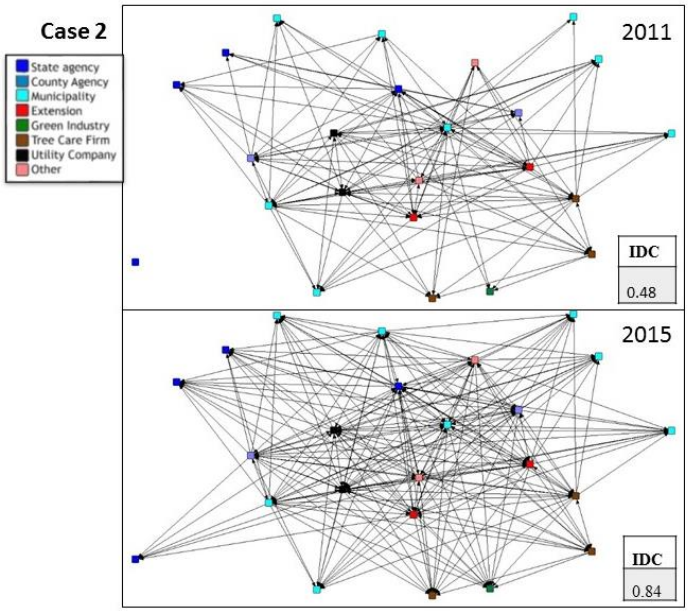
Linking

In Case 1 (Figure 2.1), in-degree centrality increased 19% among task force members; 51% of members were in contact prior and 70% after participation in the task force. This network was the smallest of the three cases: 16 people, representing state agencies, county agencies, municipal staff, citizen volunteers working with a municipality, CCE staff, members of New York State Partnerships for Regional Invasive Species Management (PRISM) and private tree-care firms.Figure 2.1. Network Maps of EAB Task Force Members in Case 1.



A county planner, CCE staff, and volunteers from municipal shade-tree boards had high centrality in the network. On average, each task force member began communicating with four other task force members. When asked who they go to for information and advice on EAB outside of the task force, three task force members listed regular contact with a university researcher.

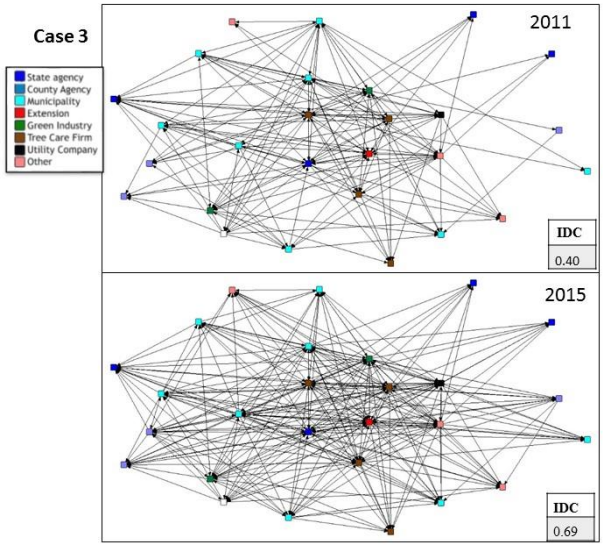
Figure 2.2. Network Maps of EAB Task Force Members in Case 2.



Task force members in Case 2 (Figure 2.2) increased their connections from 48% to 84% of members having contact with each other. The task force included 24 people, representing state, county and municipal staff; private tree care firms, private utility personnel, and CCE staff. County personnel, CCE staff, and one municipal representative had high centrality in the network.

On average, each task force member began communicating with nine other members. Six task force members named researchers at two separate universities whom they regularly went to for information and advice on EAB.

Figure 2.3. Network Maps of EAB Task Force Members in Case 3



Task force members in Case 3 (Figure 2.3) increased their communication from 40% to 69% of task force members having contact with each other. The task force included 27 individuals, representing all levels of government, CCE, private tree-care firms, and representatives from pesticide-distribution firms. State agency members and a CCE agent were central actors as were private tree-care firms and pesticide distributors. On average, each task force member began communicating with eight other task force members. Six task force members named a university researcher whom they regularly went to for information and advice on EAB.

The change in mean in-degree centrality was positive across time frames for all three cases meaning that participation in the EAB task force increased links among individuals who were not previously in contact. However, a linear regression in which change in mean in-degree centrality was regressed against membership in any given task force revealed that the change in Case 1 was significantly smaller (at the 95% confidence level) than the changes in with Cases 2 and 3 ($p = 0.00157$ and $p = 0.04158$, respectively). A linear regression in which current in-degree centrality was regressed against membership in any given task force revealed mean in-degree centrality was significantly higher (at the 95% confidence level) in Case 2 than in either Case 1 or Case 3 ($p= 0.003$ and $p=0.0002$, respectively), indicating that individuals in the EAB task force in Case 2 were significantly more connected. Full regression tables are in Appendix II.

Task Force Activities and Connections to Ash Management

The descriptions below were assembled from meeting notes describing activities and practices of the task forces. Interview data were used to trace connections between actions of the task force and management actions by municipalities and counties.

Case 1

When EAB was discovered in the county in 2010, the infestation was already large and growing rapidly. A PRISM (Partnership for Regional Invasive Species Management) coordinator initiated an EAB task force. The EAB task force in Case 1 met 12 times between 2011 and 2015. Researchers gave presentations on EAB ecology and management options and research articles were distributed through the task force. Task force meetings were used to exchange information on the location of declining trees and members discussed how to mobilize municipalities and homeowners to manage their ash trees. They collaborated to construct an educational display on EAB and organized two workshops for municipal and county personnel responsible for trees. Interviewees stated that the task force enabled members to exchange information and resources.

> *I know there were some key people in the task force that really helped bringing everybody up to speed on the issue, on the severity of it. I know that [university expert] has been to several of the task force meetings. It's really been helpful too to hear what's happening in the different towns and also on the task force there are a couple of people from a tree service and... they've been able to give more information on treating the trees… and going back and seeing, over time whether that seems to be effective or not.* – Task force member, 2/6/2016

By 2015, the county was experiencing widespread mortality of ash trees. Personnel from the county and a small town at the heart of the infested area used the task force meetings to gain information and design management plans. However, execution of the management plans was

derailed by lack of personnel and funds. A second municipality removed all their park ash trees after attending the task force workshops and then used the task force for assistance in complying with wood waste regulations. Interviewees did not perceive the task force as effective in stimulating co-management or pro-active management. Budget constraints and small staff were seen as insurmountable barriers characteristic of small town and county governments. Interviewees described connections they made through the task force that they would use on future invasive species issues, such as the Asian Longhorned Beetle (ALB):

> *I think the feeling was going in that there's not much we can to do stop the emerald ash borer… but we thought it would be very good preparation for ALB… we worked with all kinds of different organizations that would, in my opinion, be needed when ALB would show up if it's not here already. We've set these things in motion now, we know who to call, who we can talk to, who's best to work with.* - Task force member, 2/4/2016

Case 2

A director in the county environmental office learned about EAB and requested that CCE staff assemble an EAB task force. The EAB task force in Case 2 met 30 times between 2011 and 2015. Conversations in task force meetings were used to discuss and gain clarity on what impacts were expected from EAB, what goals should steer management, what steps needed to be taken first and what options were available:

> *Each of these groups [in the task force] brings their own subset of knowledge that everybody else is able to benefit from. So whether it's bringing up a question we didn't know about or it's having access to resources and answers that everybody else needs. So, we're having a lot of cross learning happening about what the management problems might be, but also, what are some of the solutions that any given municipality is doing.* – Task force leader, 4/18/13

When the task force formed in 2012, there was no known EAB infestation in the county. The task force set up a monitoring program to detect EAB. The state agency contributed equipment

and expertise, the county mapped out a network of trees on county property to be girdled and felled, and volunteers coordinated by CCE provided labor. This monitoring program led to the detection of EAB in the county in 2013, and in 2014 and 2015, it was used to delimit the boundaries of the infested area and understand the rate of growth of the infestation.

County managers utilized the task force as a source of advice to develop and execute an ash management plan. Task force members helped county managers to design a tree inventory for their parks and county roads and then to use this information to develop a ten-year, $13.5 million management strategy. The strategy incorporated a complex set of ecological, social, and economic objectives including: short-term goals (liability and risk management, contractor safety, conservation of high value ash trees) and long-term goals (replanting to enable recovery of the canopy over 100 years). Personnel from utility companies and private tree-care firms provided technical information on safety standards and equipment. When the management plan was put into action, county managers realized there were no tree-care firms with the necessary experience and training to carry out such large and complex tree removals. This problem was brought to the task force, and the task force responded by organizing a training to equip local tree-care companies with the knowledge they needed. Following the training, several of the tree-care firms joined the task force, expanding the group of collaborators.

An urban forestry network existed in the county prior to the EAB infestation, including municipal staff, non-profit organizations, and citizen volunteers who regularly distributed and planted trees all over the county. Interviewees indicated that these relationships accelerated the collaborative process in the task force:

> *…there is a long standing experience, with each other. We know each other's areas of focus, strengths and weaknesses. And you know we all try to respect each other. Like _____ does not to do a lot of environmental education, that is _____'s role but we*

> *do a lot of the survey design build and project management.* - Task force member, 2/11/2016

The urban forestry network enabled rapid communication of information on EAB to municipalities. Four municipalities planned and began to implement tree removals as a result of their participation in the EAB task force, benefitting from the experience of the county. Although participation in the task force waned as goals were met, task force members identified that the relationships they built would be easily activated to deal with another invasive species or natural resource management issue:

> *So now we've got … more capacity and more resiliency, I think, to be able to address these topics, not just Emerald Ash Borer but other things, because we have diversified the range of groups and agencies and businesses being involved, but also what any of those individual groups can do.* - Task force leader, 1/27/2016

Case 3

When EAB was found in this county in 2011, a PRISM coordinator initiated the EAB task force, that met 20 times between 2011 and 2015. Task force members wrote a mission statement early on, defining the purpose of the group as:

> *a volunteer organization of forestry resource professionals, scientists, natural resource managers, local officials and private citizens assembled to assist local, state and federal EAB programs and to facilitate a science based response to the economic, ecological and public safety impacts of EAB within the forests and communities of [the area]*.

This statement indicates a shared vision among the parties represented. Personnel from the New York State Department of Conservation conducted a survey of all municipalities in the county to assess their knowledge of EAB. By collaborating with the task force to distribute the survey, they received a high response rate. Subsequently the task force organized workshops targeting these municipalities for EAB management planning. Collaboration between municipal personnel

and state agency members on a separate workshop for homeowners in an infested town generated high turnout and enthusiasm among town residents.

Nine municipalities and the county began managing their ash trees after participation in the task force. Interviewees identified three connections between the task force and these management actions. Partnerships between state, county and municipal personnel (vertical linking) increased the efficacy of an EAB community survey and preparedness workshops, enabling the task force to reach more of the municipalities than the agencies would have on their own. Horizontal linking among personnel from different municipalities created the opportunity for learning from one another about EAB management questions specific to their context as illustrated in this quote from a task force leader

> *Knowing I would be doing one of these [ash management plan], we're asking what are other people doing, being part of the meeting where everybody gets the update about any activities in the town. We're seeing what they're working on.* – Task force leader. 2/10/2016

Lastly, cooperation on grant writing enabled task force participants to access funds for management.

Interviewees described the development of new relationships among county agencies, municipal personnel, and state agencies as an important outcome that would last beyond EAB.

> *For some of these communities it has sparked, hopefully a more long term approach to their overall street tree care. Not just with the ash. And so I think that it has empowered some communities that will be doing more as a result of the ash borer.* - Task force member, 2/9/2016

Results Summary

The cases presented represent a natural experiment in ACM. In each task force, stakeholders came together to learn about EAB, evaluate their ash resources, and create strategies to mitigate the damage from EAB in their counties. Task force members in all cases reported cognitive learning; i.e., an increase in their understanding of EAB. However, differences were identified among the cases with respect to the density of the networks and outcomes for management.

The county in Case 1, a rural county with low population density, was experiencing an advanced EAB infestation with dead and dying trees prominent along many county roads. Task force members articulated benefits from the information exchanged in task force meetings and they established new connections with other task force members; however very little management action emerged. The county in Case 2 was an urban/suburban county with a small, early stage EAB infestation. Significantly more new connections were formed actions taken (e.g., EAB monitoring program, a county ash management planning process, and municipal planning processes) in Case 2 than in the other cases and the task force demonstrated joint learning-in-action (members devised solutions when barriers to management arose). Relational learning characterized the task force process in Case 3, an urban/suburban county with a large low-intensity EAB infestation. The members of this task force were the least connected prior to the task force; involvement in the task force increased their communication and cooperation with other task force members; and collaboration among municipal, county and state participants drew municipalities into the management planning processes, where they benefited from cooperation on grant writing and sharing experience.

DISCUSSION

The purpose of this study was to investigate adaptive co-management processes and outcomes in the context of invasive species. I have conceptualized learning and linking as two interrelated functions, and have presented case studies of local task forces. In applying Plummer et al.'s (2014) diagnostic framework to three local task forces for EAB, I found evidence of cognitive, normative and relational learning among task force members. I documented increases in connections or links among public and private stakeholders spanning multiple levels of government.

Below I discuss potential reasons that management outcomes differed among the cases and the implications for the capacity of the communities in my study. I then outline types of learning relevant to invasive species management.

Knowledge Networks and ACM

In this section I explore underlying elements of community capacity that impacted the ability of the EAB task forces to respond to EAB. I use the categories provided by Fabricus et al. (2007) of powerless spectators, coping actors, and adaptive co-managers. Two characteristics that impact the capacity of communities to utilize ACM and adapt to changing conditions are the demographics of the communities and the presence of knowledge networks (Fabricius et al., 2007). I build on this framework by suggesting that knowledge networks are dynamic and may increase community adaptive capacity through iterative attempts to use ACM.

The finding that in all three cases, actors from different levels of government and from private firms who were not previously in contact were linked through the task forces, indicates that the actors in these counties face fragmented organizational structures and compartmentalized decision making that often characterize multi-level government systems (c.f. Olsson, Folke, Galaz, Hahn, & Schultz, 2007). Through face-to-face meetings, connection was established vertically and horizontally, among stakeholders in municipal, county and state levels of government and non-governmental actors. Dialogue facilitated the integration of diverse perspectives, agreeing with Berkes et al. (2009) that co-management can be seen as a knowledge partnership where individuals from different levels of organization contribute to the pooling of different types of information. Ernston et al. (2010) argue that pooling information from decentralized sources is critical to enabling stakeholders to prepare for a disturbance. However, interventions to promote ACM are time and resource intensive. It is necessary to consider the translation of the information into management actions to meet the goal of mitigating invasive species impacts.

Stakeholders in the EAB task force in Case 1 gained new knowledge of EAB and new connections with each other, but experienced insurmountable barriers to pro-active ash management. County and municipal governments did not have the personnel or money to keep pace with the rate of dead and dying trees. The county described in Case 1 has a shrinking, aging population in a small city and towns, with few resources at their disposal, resulting in a low capacity to react to a disturbance such as EAB. This finding agrees with previous literature synthesized in Fabricius et al. (2007) that depopulation or low population levels can reduce the capacity of a community to respond to environmental issues through lack of monetary and human resources. Stakeholders also had less time to react as a result of the advanced stage of the

EAB infestation. Despite the presence of the task force, the community in Case 1 could be described as a "powerless spectator" to the impacts of EAB.

Although ash management took place in both Cases 2 and 3, the result that task force members in Case 2 reflected on whether goals had been met and took new actions as a result indicates a higher capacity for joint learning-in-action in Case 2 than in Case 3. The pre-existing relationships among task force members in Case 2 likely accelerated the development of a common vision and collective goals and contributed to adaptive capacity (Fabricius et al. (2007). When knowledge of an area's natural resources, governance history, and key role players exists within a network of actors, a greater awareness of the processes underlying social and ecological systems is present and their capacity to learn is higher (Fabricius et al., 2007). Case 2 reflected pro-active planning and investment in long-term canopy preservation, characteristics of adaptive co-managing communities (Olsson et al., 2004).

The results that relationships among stakeholders in various levels of government and sectors of society increased in all three cases, and that task force members anticipated these new relationships to extend beyond EAB, indicates that knowledge networks were built to varying degrees across all three cases. This finding is in agreement with the findings of Plummer and Fitzgibbon (2006, 2007) and Newman and Dale (2004) that iterative interactions among stakeholders can cause network formation, increasing the density of the network and potentially increasing the adaptive capacity of the community. The formation of these new ties among previously unconnected actors suggests an increase in the potential for communication and trust-building and eventually social learning, that together represent an increase in adaptive capacity. I extend this thinking to present evidence of knowledge network building in rural and urban counties, with different underlying community capacity and suggest that local governments may

need help engaging in multi-stakeholder learning processes. Educational programs for invasive species management should then consider not only communicating information but also stimulating multi-stakeholder approaches and creating learning platforms for stakeholders.

Learning in Invasive Species Management

This section builds on the Baird et al. (2014) framework for cognitive, normative and relational learning to suggest that analysis of learning specific to a resource context may enable further clarification of who needs to learn and what needs to be learned to respond to environmental change. One area that requires further clarification is in the use of the term learning to describe both an individual acquiring knowledge that is new to them and the generation of new knowledge about the social-ecological system that is responding to a disturbance. To do this, I identify types of learning needed in invasive species management. This is not an exhaustive list, but preliminary insights gleaned from the case studies in this paper on three types of learning highly relevant to invasive species.

First I address the "newness" of invasive species, which requires stakeholders to have access to and absorb new cognitive information. Second, I discuss the production of ecological information on the spread of the invasive species across the landscape. Then, I discuss how shared action and reflection among stakeholders can produce knowledge of their social system as a means of overcoming barriers to invasive species management and building adaptive capacity within the social system.

With the discovery of each new invasive species, research on the species followed by rapid and effective research communication is required (Bayliss et al., 2012; Esler & Prozesky, 2010; Kueffer & Hadorn, 2008). A gap between research and practice has been documented where

invasive species managers rely more on websites and their own experience than published research when research-based information is not easy to access or does not address their questions (Bayliss et al., 2012). In addition to a lack of access to research-based knowledge, research on applying or implementing invasive species management is underrepresented in scientific publications, particularly knowledge that incorporates the social-political context of management (Esler & Prozesky, 2010; Matzek et al., 2014). The finding that the task forces resulted in cognitive learning about EAB through interactions among researchers and managers, indicates that the task forces were an effective tool for the communication of research-based information on EAB. This finding confirms findings by Crona and Parker (2011) and Lauber et al. (2011) that direct contact and dialogue among scientists and managers can enable managers to translate the scientific information into terms that make sense in their own context, a prerequisite for knowledge utilization. This direct dialogue among researchers and managers can narrow the knowing-doing gap in invasive species management.

Producing knowledge about the local ecological conditions in an infestation is another form of learning required for invasive species management. Localized distribution data of the invasive species is essential for well-informed management planning. Cash and Moser (2000) describe a scale discordance problem where climate change information produced by researchers was not detailed enough to be useful to local decision makers. Scale discordance also applies to invasive species. The finding that in each EAB task force, information was pooled or produced on the distribution of EAB suggests that task forces may address the scale discordance issue through generating information locally on species distribution. Schneider (2014) and Maguire (2004) describe the power of networks of volunteers, managers and researchers in the monitoring of invasive species populations. Our findings agree, demonstrating that stakeholder groups, such as

local task forces, are uniquely positioned to produce this information. Population distribution data was a major need in the case of EAB, as the situation changes so rapidly. In the case of other invasive species, other types of ecological information may be required, such as monitoring the efficacy of a management strategy. Where local stakeholders (including locally-based researchers) can be empowered to produce such assessments, the information produced will not only be at the right scale for decision makers, but may answer questions that are pressing to managers but not addressed in scientific publications.

In addition to ecological knowledge, knowledge about the "social system" engaged in management needs to be produced to enable local governments to respond to disturbances from invasive species (Matzek et al., 2014). Across all cases, knowledge of the institutional structures, the individuals who make up these institutional structures, and key policies that enabled or disabled management emerged from the task force process. Some of this knowledge was already presence in Case 2 allowing better short- and long-term outcomes to occur as a result of the capacity within the task force for shared action and reflection, more complex monitoring, a deeper consideration of management tradeoffs, problem-solving, and ambitious goals for canopy restoration. Task force members in Case 2 also generated knowledge about the capacity of the tree-care services market in their county to absorb the demand for tree removals. This type of knowledge generation enhances the fit between the ecological and social systems (Hahn et al., 2006).

It is estimated that around 4,300 unique invasive species are causing ecological, social and economic damage in the U.S (Fish and Wildlife Service, 2012). New invasive species are also discovered frequently. This creates a naturally iterative process where stakeholders learn about

the species after it has been discovered, assess its distribution, and initiate management activities. The stakeholders who are impacted differ from species to species, however universities, federal and state agencies and other programs (such as the PRISMs discussed in this paper) are involved in the management of many species. These institutions should use approaches that build capacity in local communities. An iterative process of network building and shared learning can build capacity of local governments and enable them to respond to invasions.

CONCLUSION

In this study, learning and linking were viewed as functions that could be increased through an intervention for invasive species management. My findings indicate that the task forces enabled stakeholders to learn about EAB, one step towards overcoming the science communication challenges of invasive species. I also documented new connections made among government and private sector stakeholders in each county and pooling of knowledge from the sources they represented. Task force members jointly produced knowledge on the areas infested with EAB in their counties. However, new knowledge alone was not enough to enable management action in all cases. I explored differences in adaptive capacity among the cases related to the demographics of the county and the presence of pre-existing knowledge networks.

I explored the implications for the use of ACM in invasive species management to close the research-implementation gap and to facilitate the co-production of knowledge. Based on the cases in this study, the increases in network density and communication among stakeholders indicate the strengthening of knowledge networks and may facilitate adaptive and collaborative responses to future disturbances, even when networks were sparse, as in Case 1.

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Chapter 3: Extension as a Bridging Organization: Developing collaborative partnerships for environmental governance

INTRODUCTION

Communities across the US face many environmental problems such as invasive species, zoonotic diseases, water scarcity, drastic weather events, and climate change. Individuals and organizations working at different spatial levels have access to different types of knowledge that can help communities respond to these problems. Community gardeners, bird-watching associations, and park and cemetery managers observe important patterns and changes in ecosystem dynamics in the patch they interact with daily (Colding, Lundberg, & Folke, 2006). Municipal and county governments retain institutional knowledge about the green infrastructure that they maintain (Ernstson et al., 2010). State and federal governments provide regulatory information and together with university faculty are often a source of specialized knowledge on ecosystems and environmental problems. Regional and national firms provide insights on technical innovations that support environmental management.

Integrating these different sources of knowledge can improve governance of environmental systems. Our ability to recognize gradual changes in ecosystem dynamics may depend on engaging diverse actors at different spatial levels (Ernstson et al., 2010). Some regions and cities have made strides towards effective, comprehensive management of their natural resources through collaborations that cross levels of government and sectors of society (Ernstson et al., 2010; Olsson et al., 2007). This type of collaborative approach is an important advance in environmental governance (Mazmanian & Kraft, 2009).

Extension systems across the U.S. are well positioned to initiate collaborative ventures that cross spatial scales and include public and private partners. University-based Cooperative Extension systems across the US have a history of convening groups for collective problem solving as described by the extension historian Wayne Rasmussen (1989). "Extension specialists in rural and community development are building educational programs with a dual purpose. They foster an understanding of the role of natural resources in the quality of both urban and rural life, and they encourage affected parties to cooperate in making assessments and developing public policy" (Rasmussen, 1989: 205).

In this paper, I propose that extension staff at universities and in counties can serve as bridges connecting people across scales and sectors to integrate different types of knowledge. First, I describe concepts related to bridging and organizations that facilitate bridging. I then present a case study of how the extension system in New York State facilitated bridging among key stakeholder groups in multiple locations to support management of the emerald ash borer, an invasive beetle causing widespread mortality of ash trees. I argue that intentional bridging is a key role university and county extension staff can play to support environmental governance.

BRIDGING AND BRIDGING ORGANIZATIONS

Bridging across levels of government and sectors of society creates possibilities for coordinated action to address environmental problems (Stubbs & Lemon, 2001). Often task forces or working groups are used to bring together managers, private citizens, business people and researchers (Crona & Parker, 2012; Hahn et al., 2006). Bridging supports environmental governance in two

ways: (1) pooling knowledge from diverse actors to prepare for disturbances, and (2) initiating collective action to respond to disturbances (summarized in Ernstson et al., 2010). Examples of this type of bridging occur in water management (Crona & Parker, 2012), air quality control (Stubbs & Lemon, 2001), urban ecosystem renewal (Ernstson et al., 2010), and wildlife management (Raik et al., 2005; Schusler et al., 2003). Contact between managers and researchers can increase research utilization on the part of managers; however, the development of a shared vision may also be required (Crona & Parker, 2011; Lauber, Stedman, Decker, & Knuth, 2011). When individuals from organizations with different objectives are brought together into a task force or working group, leadership is needed for participants to develop a common vision and shared goals (McMullen & Adobor, 2011; Yaffee & Wondolleck, 1997).

The role of leadership in bridging initatives is different than in single agency, hierarchical settings. Leaders in collaborations between multiple organizations often have no formal or hierarchical power over the individuals they are working with and as a result, they have to earn the respect and loyalty of collaborators (McMullen & Adobor, 2011; Wondolleck & Yaffee, 2000). Bridging leaders may rely on goodwill and personal relations to garner commitment and support within the network (McMullen & Adobor, 2011). Key individuals can help frame a bridging initiative by providing a vision of ecosystem management based on their recognized expertise (Olsson et al., 2007). A facilitator can also frame the collaboration by introducing norms of operation that benefit all participants (Agranoff & Mcguire, 2001), for example actively soliciting input from all participants in a meeting. When an organization convenes meetings and facilities communication it lowers the cost of collaboration for all participants (Folke et al., 2005).

Bridging organizations act as conveners, creating spaces or platforms to enable actors to work together (Brown, 1991) and have the potential to promote long-term learning for environmental governance (Berkes, 2009; Carr, Wilkinson, & Carr, Anna, 2005; Crona & Parker, 2012). The Ecomuseum Kristianstads Vattenrike (EKV) is an example of a strategic bridging organization, that enhanced ecosystem management in an ecologically important region in Sweden (Hahn et al. 2006). The EKV operates as an office of the City of Kristianstads and facilitates three types of bridging groups: consultancy groups to shape overarching goals and build trust among key public and private partners; theme groups to bridge local users, conservation groups and researchers for purposes of engaging with specific resource types such as flooded meadows or groundwater (Olsson et al., 2007); and adhocracy groups that emerge in response to a specific problem, rely on activating latent relationships, and last as long as the problem demands (Hahn et al., 2006).

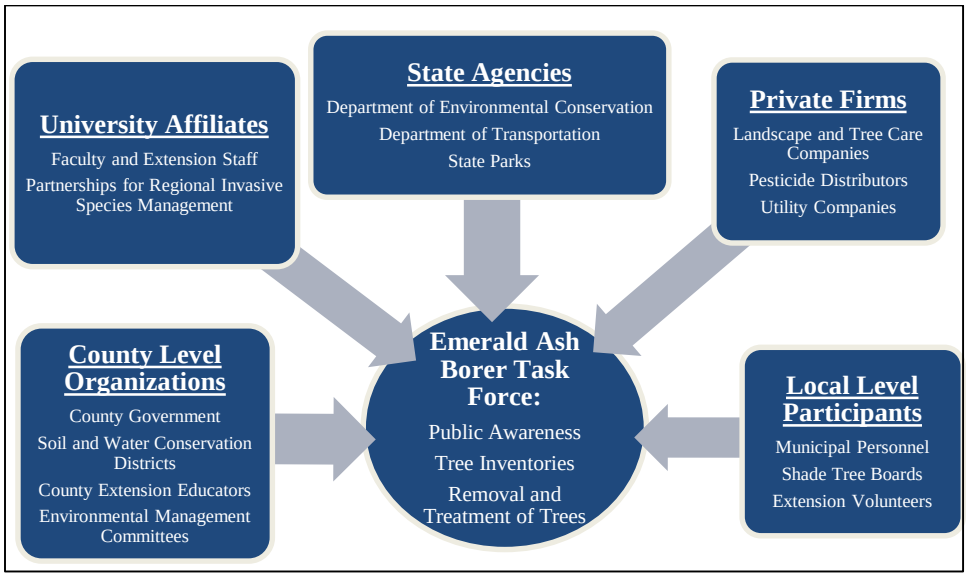
EMERALD ASH BORER AND COMMUNITY TASK FORCES

This case study is set in New York where the emerald ash borer (*Agrilus planipenis)* is having a large impact on rural and urban forests. The emerald ash borer (EAB) is an invasive beetle, first found in Michigan in 2002, that causes widespread death of ash trees (*Fraxinus*). Local governments and homeowners are heavily impacted by EAB through expenditures for tree removals and losses to ecosystem services and property values (Aukema et al., 2011).

When EAB was discovered in New York in 2009, an extension associate in forest entomology in the Department of Natural Resources at Cornell University, Mark C. Whitmore (MCW), began a campaign of public presentations across New York to raise awareness of EAB and the need for

pro-active management. However, gaining the attention of municipal and county managers proved difficult and few municipal or county governments initiated planning activities. Where managers understood the scope of the problem, difficulty arose in translating general information on EAB into specific management plans. To overcome these challenges, MCW initiated a program of EAB task forces as "ad hoc" platforms to help communities prepare for EAB (Figure 3.1). Through analysis of EAB impacts in the Midwest, he identified stakeholder groups (Whitmore et al. 2011).

Figure 3.1. Concept Map of a Local EAB Task Force.

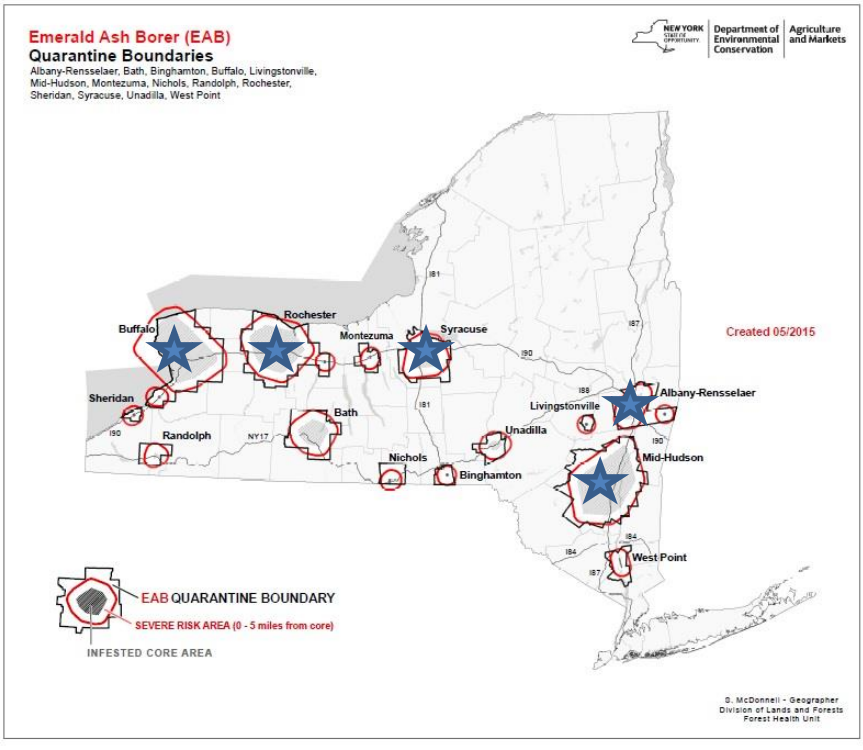


As part of a separate study on adaptive co-management and invasive species, I collected data on the formation of networks, learning, and outcomes that occurred in three EAB task forces using an online survey (n=67) and in-depth interviews (n=12) (for complete methods, see Chapter 2.) The following sections utilize these data and information I compiled from meeting minutes and participant observation of task force meetings.

Recruiting Stakeholders

Through giving presentations on EAB, MCW developed a state-wide network of individuals and organizations already engaged in invasive species management who recognized the impending impacts of EAB and were ready to take action. Initial collaborators included county extension staff focused on urban forestry and pest management, New York State Department of Environmental Conservation (NYSDEC) foresters, and staff from the New York State Partnerships for Regional Invasive Species Management (PRISM). These collaborators organized EAB task force meetings and identified and invited stakeholders using their own professional networks. Five task forces met regularly or sporadically from 2011 to 2015 (Figure 3.2) engaging around 200 people total.

Figure 3.2. New York State Department of Environmental Conservation (2015) map of EAB infestations in New York. Areas marked with stars had sustained EAB task force meetings between 2011 and 2015 (Conservation, 2015, pg 1).



I used social network analysis to visualize collaboration in three of the EAB task forces. A map of network ties within and between EAB task forces (Figure 3.3) revealed the central role of university and county extension staff. The number of individuals (extension staff and others) in each task force who independently cited MCW (Node 1) as a source of information reveals his influence and leadership. Through the task force project, county extension staff (in yellow) increased in centrality, gaining a more prominent position among stakeholders and serving as bridgers. However, extension staff were not the only bridgers. Nodes 3, 4 and 4 and 5 are representatives of large pesticide distribution firms. Private firms played a role linking the EAB task forces to municipalities, as ongoing contracts and business relationships existed between these firms and municipalities. Node 6 is a federal agency involved with invasive species. Although network mapping did not show personnel from the state environmental agency to be bridgers, meeting minutes and interview data indicated that NYSDEC foresters played a vital role in linking task force members to state services, such as grants and information on regulatory compliance.

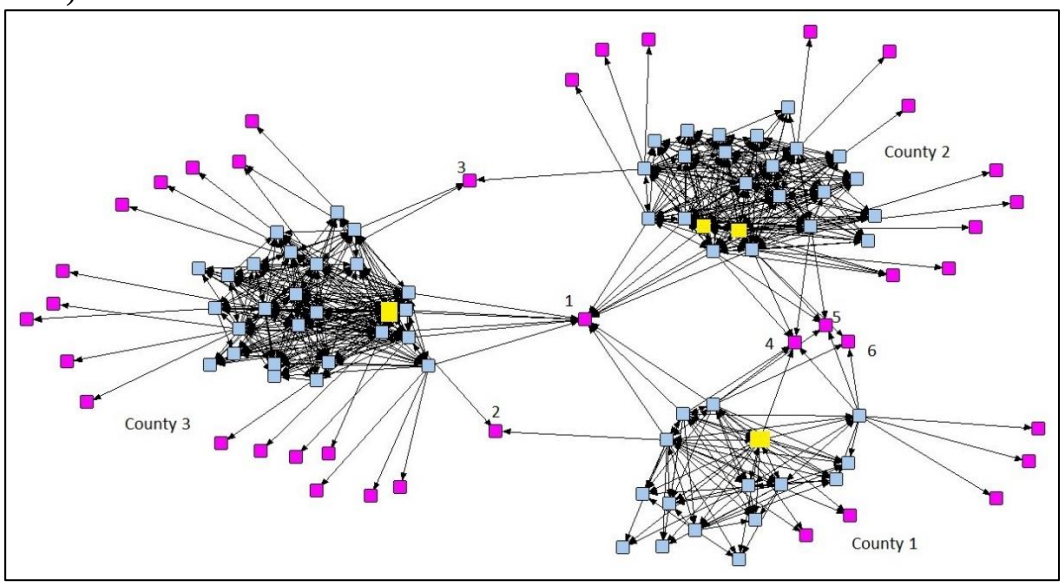
Developing Common Goals

In four of the EAB task forces, county extension staff convened and facilitated the task force meetings; the fifth was chaired by personnel from the county government. The county extension staff had several important facilitation roles: encouraging all task force members to contribute to discussions, managing potential sources of conflict, and working to find shared objectives. Mission statements were developed in two of these task forces; an example is given below:

"The [task force] is a volunteer organization of forestry resource professionals, scientists, natural resource managers, local officials and private citizens assembled to facilitate a science-

based response to the economic, ecological and public safety impacts of EAB within the forests and communities of the [ ] region of New York."

Figure 3.3. Network map of three task forces. Blue nodes are task force members and pink nodes are individuals or organizations they identified that they go to for support, advice, and information on EAB outside of the task force. Yellow nodes are county extension staff and nodes 1 and 2 are university extension staff. Network Map was produced in UCINET (Borgatti et al., 2002).



These county extension facilitators worked to resolve potential sources of conflict when stakeholders' objectives differed. For example, extension facilitators discouraged tree-care firms from overt marketing activities at task force events and ensured that the task force did not promote one tree-care firm over another. When EAB was discovered in a county with an active EAB task force, tension arose between state agency protocols and the interests of local stakeholders in how and when to publicly announce the discovery. The extension facilitator helped facilitate communication between state agency personnel and local stakeholders to come to a resolution.

MCW visited all EAB task forces to highlight the urgency of ash tree management in light of the growing size and intensity of EAB infestations and to clarify management options. In addition,

"Task Force Exchanges" were organized by MCW and his assistant where facilitators of different task forces around the state were invited to meetings to exchange experiences, strategies and approaches, and to discuss challenges that each task force was facing. By discussing common barriers, such as the perception of political apathy, and by reframing the problem into a question, "how do we help municipal managers learn about EAB and consider their management options?", task force facilitators were able to identified useful steps to take.

Pooling Knowledge

Task force meetings were used to pool, digest and synthesize knowledge. In task force meetings, county extension facilitators asked each participant for updates to increase engagement and draw out different types of information. In the quotation below, a task force participant discusses the different points of view and the different needs of task force members.

> *It's important to have the folks that are doing the treatment from the green industry who are out there, talking to land owners and the DPW [Department of Public Works] folks… People are coming at this from different points of view. If you're a municipality, you're looking at liability and I need to do an inventory and take care of the problem. And other folks are more concerned about homeowners.* - NYSDEC forester

Management planning was a major topic of conversation in all EAB task forces. As a CCE facilitator discusses in the quotation below, participants were eager for information and used task force meetings to sift through and synthesize research, and to make it applicable to their circumstances by bringing in local information such as tree inventories. In four of the task forces, counties and municipalities planned and carried out tree removals and treatments as a result of their task force involvement.

> *All of these people who showed up and knew that they had to do something, [the task force] gave them the information and helped us ask the right questions, really get into the*

questions, reveal things that we didn't know we had to think about, but also discard stuff that we thought was important that really wasn't. - CCE educator

Initiating Collective Action

Leadership within the task forces determined the ability of the group to translate their mission and objectives into action. All five task forces put on public presentations and workshops targeting homeowners and municipal highway crews. These educational activities increased awareness of EAB but the link to management action was less clear.

Two of the EAB task forces produced maps tracking the growth of the EAB infestations. Task force members reported new locations of dead and dying ash trees to county extension facilitators, which NYSDEC foresters compiled into detailed maps that municipal and county parks and highway managers could use to inform their planning processes.

Four task forces contributed to the development of county ash management plans, but only two of the five task forces were successful in spurring municipalities to carry out tree removals or treatments. Untangling all the reasons for the different outcomes is beyond the scope of this paper; however, these two task forces were facilitated by dynamic county extension staff members. A potential future area of development for county extension staff may be in facilitation techniques and bridging leadership.

DISCUSSION

I have described how university and county extension staff created task forces that acted as bridges among public and private stakeholders to disseminate knowledge and promote invasive species management. These bridgers helped forge a common vision among diverse stakeholders and encouraged participants to exchange information and pool knowledge from various spatial

levels and organizational perspectives. University and county extension were only two parties in a multi-party collaboration; however, they were able to provide unique leadership.

Extension as a Bridging Organization

The case I have presented highlights qualities that uniquely position extension staff to facilitate bridging. In response to the impending EAB crisis, a network of people concerned about the issue emerged. MCW capitalized on his position as a respected expert in this network to suggest that EAB task forces be formed. That task forces formed highlights a component of bridging leadership identified by Olsson et al. (2007); i.e., in a time of disturbance, MCW was able to convey a vision of the issue that mobilized individuals to take action. Some of this leadership may be associated with MCW as an individual. However, many extension staff have influence in the networks in which they work by virtue of their expertise, university affiliation, and association with the mission of extension.

County extension staff used their reputation and position in networks in their county to link diverse actors or groups to tackle a problem none could solve on their own, which is the definition of a bridging organization described by Brown (1991). Consistent with descriptions of bridging in Crona and Parker (2011) and Olsson et al. (2006), the task forces enabled researchers and managers to collaborate on translating ecological and technical knowledge into management plans. Private tree-care firms were also engaged in the process and made unique contributions to expanding the network of concerned individuals. In some cases, these private firms operated as bridges, too. However, to make the collaboration productive, effort was required to develop a shared vision, which fell to MCW. In two of the EAB task forces, dynamic county extension facilitators also helped to develop shared goals and objectives and to track their progress towards

these objectives, as well as mitigate sources of conflict. This type of process management and skillful negotiation of relationships is indicative of factors that promote bridging (Yaffee & Wondolleck, 1997). The fact that extension systems are not state agencies or market actors enables university and county staff to create neutral ground for collaboration among stakeholders.

Uncovering factors that lead to productive bridging initiatives is an important area of further investigation. Rich collaborative relationships and collective action do not emerge from all task forces and working groups. For extension to play a role in bridging, it is crucial that county extension staff have the ability to facilitate discussion that yields well-defined shared objectives and actions to take to meet the objectives. Differences in outcomes among the task forces may be related to this capacity on the part of the task force facilitators, whether they were county extension staff or not.

Civic leadership and organizing has a history in extension programming: M.L Wilson, the director of the national Cooperative Extension system in 1940 declared:

> *Extension workers and others who are charged with assisting in the development of programs to meet not only current needs, but also the changing needs of the world are vitally concerned with questions of leadership… their primary job is to help the community analyze its problems in the light of all available information and so to organize itself that the necessary action can be taken.* - (Wilson, 1940, pg 4).

EAB and the resulting widespread tree mortality is a disturbance that requires local governments and homeowners to make management decisions. Creating the right links at the right time is thought to be crucial to enabling governments that are compartmentalized and fragmented to respond to disturbances (Olsson et al., 2007). Consolidating information and organizing for action will require a different set of actors depending on the issue at hand. The breadth of

expertise and networks to which university and county extension staff are connected position them to convene groups for bridging on many issues. The result, as shown in this case, would be a powerful network for contributing to environmental governance spanning levels from national to neighborhood.

CONCLUSION AND RECOMMENDATIONS

I have described an experience of university and county extension staff working jointly to bridge stakeholders and support management of an invasive species. University and county extension staff worked together to identify and form groups of stakeholders, creating EAB task forces. County extension staff facilitated the development of collective goals and objectives in the EAB task forces and managed sources of conflict. These actions created a collaborative environment that produced collective action for ash management, public education and monitoring of the spread of EAB.

Moving forward, Natural Resource extension staff at the university level should identify where bridging can be productive to address other issues, and purposefully design bridging interventions by identifying stakeholder groups and creating platforms for collaboration. Acting as a bridging organization on an increasing number of issues positions extension systems to make a crucial contribution to environmental governance.

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Chapter 4: Discussion and Conclusion

INTRODUCTION

In this thesis I have investigated a process of learning, linking and bridging among researchers and resource managers in response to rapid disturbance from an invasive species. In this chapter I discuss key findings from Chapters 2 and 3, explore relationships between these findings, and identify implications for theory, practice and further research.

DISCUSSION OF KEY FINDINGS

In Chapters 2 and 3, I used different but overlapping conceptual frameworks to examine the role of local task forces in mitigating the impacts of an invasive species, the emerald ash borer (EAB). In Chapter 2, I used adaptive co-management (ACM), that combines the "learning function" of adaptive management and the "linking function" of co-management (Plummer et al., 2012), to develop case studies of three EAB task forces. I assessed learning among task force members by looking for evidence of cognitive, normative and relational learning (c.f. Baird et al. 2014); examined the formation of networks using social network analysis; and made connections from the activities of the EAB task forces to ash management plans and actions, focusing on municipal and county management. In Chapter 3, I summarized literature on bridging and bridging organizations and then used the EAB task forces as a case study of the role of extension systems in facilitating bridging. In this section, I will discuss key findings from Chapters 2 and 3 including the role of knowledge networks, resource-specific types of learning, and bridging leadership.

Findings in Chapter 2 shed light on how knowledge networks increase the ability of communities to address invasive species impacts through joint learning in action. I also described in Chapter 2 how an initiative to bring stakeholders together can build knowledge networks. Knowledge networks enable actors who are working at different levels to share information, increasing the knowledge base for management and creating new awareness of the social and ecological system (Fabricius et al., 2007; Olsson et al., 2006). When knowledge of an area's natural resources, governance history, and key role players exists within a network of actors, a greater awareness of the processes underlying social and ecological systems is present and the capacity for joint learning among actors in the network is higher (Fabricius et al., 2007). This awareness can develop rapidly through a disturbance or crisis (Olsson et al., 2004); however networks are more powerful when they address long term resource management in addition to crises. The term "shadow networks" was introduced by Olsson et al. (2006) to describe networks that may develop alongside conventional institutional networks, but emphasize knowledge exchange and cross-organizational learning. Since members of these networks are often not in the same organization or agency, they are freed of organizational norms that can hinder learning, such as bureaucratic or hierarchical modes of operation, enabling them to learn from each other and think creatively about how to resolve resource problems (Olsson et al., 2006). Developing these shadow networks through invasive species crises is promising, however, sustaining these networks requires coordination and leadership (Hahn et al., 2006).

Findings in Chapter 2 also pointed to types of learning needed for invasive species management. I identified three types of learning particularly relevant: cognitive learning by task force members about EAB, expected impacts and management options; the production of ecological knowledge of EAB populations; and the production of social knowledge of the organizations,

institutions and policies affecting ash management. These types of learning represent both ecological and social learning, agreeing with Matzek et al. (2014) that to deal with invasive species, managers need to engage with the social, political and economic context in addition to the ecological context of the invasion. From these findings, I suggest that a promising avenue for future research in learning for environmental management is to consider and characterize learning needs relative to particular resource situations. The relationship between learning in ACM and public participation in scientific research (Shirk & Ballard, 2012) or problem oriented landscape research (Kueffer & Hadorn, 2008) would be an interesting avenue to explore. Both of these frameworks aim to describe how researchers, managers, citizens, or other stakeholders collaborate to produce knowledge. They raise important questions about the boundary between scientists and managers, and whose interests are being served in various types of participatory research. The literature on learning in ACM thoroughly engages with learning by individuals. However, more can be done to clarify how stakeholders may produce new ecological and social knowledge as they struggle to manage their resources in the face of disturbances and environmental change. Empowering stakeholders to produce knowledge is a potential path to building capacity in communities for adaptive management.

Managing the development of knowledge networks and empowering stakeholders to learn requires leadership and vision (Fabricius et al., 2007; Olsson et al., 2007). In Chapter 3, I engaged with the literature on bridging and bridging organizations to analyze the potential of extension systems to facilitate bridging. Two key findings were that the multi-level nature of Cornell Cooperative Extension enabled the development of networks of stakeholders that also crossed levels (state, regional, county, municipal) and that university and county extension staff provided leadership that supported bridging through communication of the issue in a way that

built common purpose, managed sources of conflict, and facilitated information exchange. Leadership in bridging situations differs from other forms of leadership; since the leader has no direct organizational authority over participants they must gain respect, goodwill and loyalty from collaborators in the bridging initiative (McMullen & Adobor, 2011). This is a capacity of charismatic leaders. However, for extension systems to support bridging on a large scale, it is necessary to go beyond individual leadership qualities and consider how organizations or agencies can provide vision and leadership. The Ecomuseum Kristianstads Vattenrike (EKV) is an example of a strategic bridging organization, that enhanced ecosystem management in an ecologically important region in Sweden (Hahn et al. 2006). This organization has taken specific strategies and approaches to overcome constraints to bridging, such as using a landscape perspective to help actors perceive their interdependencies and understand the need to work together, organizing interactions among actors to develop personal relationships and build trust, and providing participants with joint ownership of processes and outcomes (Olsson et al., 2007). An area for further research is how extension systems can provide similar bridging leadership across different natural resource issues.

Although I have mainly discussed the findings of these studies in the context of invasive species management, there are implications for governance. Whereas management involves operational decisions to achieve specific outcomes, governance refers to broader processes of decision making that impact human-environmental interactions (Armitage, de Loë, & Plummer, 2012; Oakerson, 1992). Environmental governance refers to the system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that may be able to steer societies toward preventing, mitigating, and adapting to global and local

environmental change within the normative context of sustainable development (Biermann, 2009).

In this thesis, I have described a response to disturbance that built knowledge networks and stimulated the production of ecological and social knowledge. Strengthening these knowledge networks may assist in a transition towards forms of governance, characterized by actors collaborating without a dominating governing actor, that Kooiman (2003) theorizes may be better equipped than other modes of governing (such as hierarchical governance) to respond to dynamic and complex situations. When existing and traditional structures of authority, organization, methods and instruments are not adequately addressing environmental problems, an organizational context conducive to innovation is created. This organizational context may yield co-governance when issues of great concern to public and private actors arise, and these actors can identify and pursue shared objectives (Kooiman, 2003). Armitage et al. (2012) suggest that the success of environmental governance systems in responding to disturbances and environmental change will hinge on institutional fit; adaptiveness, flexibility and learning; the coproduction of knowledge from diverse sources; and the emergence of new actors and their roles in governance. Further research might pursue questions on how co-management of invasive species may enhance the fit between existing institutions and ecosystems and increase their adaptiveness and capacity for learning. Another set of questions exists on the emergence of new actors, such as bridging organizations, and their roles in governance.

PERSONAL REFLECTIONS

Before concluding this thesis, I would like to articulate personal insights I have gained and how I hope to apply them to my future work. I began interacting with the EAB task forces as the

coordinator of a program. In this role, my objectives were heavily normative: I wanted these task forces to help local governments deal with the impacts of EAB, and I believed that it would be more likely to happen if the task force members approached their work in a spirt of learning. I observed that many task force members drew satisfaction from working with others across organizations and levels of government, as if they were freed from norms from their own organizations that constrained them from pursuing their personal goals for environmental conservation.

In the process of conducting these studies I have gained structure in my thinking about how learning by individuals and by social groups can contribute to environmental conservation. As I began the research, I conceptualized the task forces as an isolated intervention with inputs, interactions, and the hope of outputs for ash management. My mental model has shifted to viewing the task forces as temporary platforms created in the context of existing networks. The development of knowledge networks can be a powerful force in moving towards better environmental governance. I plan to find more opportunities to facilitate learning among agencies and organizations in different resource and social settings and will bring with me a new set of theoretical tools to apply.

CONCLUSION

Invasive species are a pressing concern for biodiversity around the world and the management of invasive species has many cross-scale dynamics and knowledge issues. Local governments must increase their capacity to respond to invasive species. I have contributed a set of empirical case studies on how learning and linking can be applied for invasive species management, and the role of a bridging organization in catalyzing ACM.

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Appendix I: Interview Guide and Survey Instruments

Interview Guide

Objectives

A. To determine key informant's perceptions of the outcomes of the EAB task forces
B. To gain information from key informants on municipal and county ash management plans and actions
C. To investigate links between practices and activities undertaken by the EAB task force and outcomes

Questions:

Objective	Question
Opening and Background	How did you become involved with the EAB task force?
To determine key informant's perceptions of the outcomes of the EAB task forces	This kind of task force can have a variety of products and outcomes. I will be going through a list of possible outcomes from the EAB task force. I would appreciate your input on each and then at the end you can add in any outcomes or impacts I have missed. Provide a list of municipalities, go down the list and solicit information on: Ash trees REMOVED by MUNICIPALITIES Ash trees TREATED with pesticides by MUNICIPALITIES Ash trees REMOVED by COUNTY Ash trees TREATED by COUNTY
To investigate links between practices and activities undertaken by the EAB task force and outcomes	"You said the following actions were taken: xx, yy, zzz, now I would like to go through each one and ask if you think the task force had an influence and if the TF did….how the TF might have influenced the outcomes. • How did that happen? What are the links?

Intangible Products/Results To investigate links between practices and activities undertaken by the EAB task force and outcomes	In addition to the tangible management plans and actions that you have mentioned, what other outcomes or impacts have come out of the task force? I'm also interested in what kinds of new professional relationships or partnerships among individuals or organizations have come about through the task forces. Probes: • Educational and outreach for homeowners? • Undertaking collective actions to resolve problems? • Increased connections among participants? • New or modification of institutional arrangements (formal and or/informal) – policies, strategies, organization etc • New cooperative undertakings? "You said the happened: xx, yy, zzz, now I would like to go through each one and ask how it came about. • What habits or practices of the group of people in the task force helped or hindered this outcomes?
Expected/unexpected	Of these, where there some you expected to see? Were any unexpected?
Second order outcomes	Are there any results that you see as extending beyond EAB to other issues or projects?
Collateral impacts	Did any problems occur? Were any conflicts or controversies accidentally created?

Survey Instruments

Q0 Welcome to the Emerald Ash Borer Task Force Project Survey

Q1 What is your name?

Q2 What agency or organization are you affiliated with?

Q3 What is your position in the agency or organization?

Q4 The following questions will help us to understand the collaboration between government and the private sector and among levels of government that has gone on around the management of EAB. We are interested in how existing professional relationships and networks have supported the work of the Emerald Ash Borer task forces, and if new communication and collaboration has been established. For each person on the list below, please indicate how often you have had contact (in person, over the phone or via email) with him or her based on the following categories:

a) "How frequently were you in contact with this person below PRIOR TO becoming involved with the Emerald Ash Borer task force?"

b) "How frequently are you in contact with this person in the LAST YEAR?" Please select an answer from the dropdown list for both questions. Q5 Please think about organizations or individuals not listed above that you go to for information, advice, support, or help on EAB or ash management. Enter the name of the

	How frequently were you in contact with this person PRIOR TO your involvement with the Emerald Ash Borer task force?						How frequently are you in contact with this person in the LAST YEAR?					
	Several times a week (1) ❍	Several times a month (2) ❍	Several times a year (3) ❍	Once a year (4) ❍	Never (5) ❍	Not applicable - that's me (6) ❍	Several times a week (1) ❍	Several times a month (2) ❍	Several times a year (3) ❍	Once a year (4) ❍	Never (5) ❍	Not applicable - that's me (6) ❍

individual or organization and how frequently you have been in contact with them in person, over the phone or via email (up to 10 individuals or organizations).

	Name of individual or organization	How frequently have you had contact with this individual or organization related to EAB?			
	- (1)	Several times a week (1)	Several times a month (2)	Several times a year (3)	Once a year (4)
1 (1)		❍	❍	❍	❍

Q6 Please think about organizations or individuals not listed above to whom you have given information, advice, support or help on EAB or ash management. Enter the name of the individual or organization and how frequently you have been in contact with them (up to 10 individuals or organizations).

	How frequently have you had contact with this individual or organization related to EAB?				Name of individual or organization
	Several times a week (1)	Several times a month (2)	Several times a year (3)	Once a year (4)	- (1)
1 (1)	❍	❍	❍	❍	

Q22 Below, we have listed categories of activities common in areas dealing with the emerald ash borer. Please consider each category and in the space below list or describe activities that you have participated in. Education and outreach activities (ex. giving a presentation on EAB, manning a table at a public event, preparing a pamphlet or other educational material)

Q23 Activities related to monitoring (ex. examination of ash trees for signs and symptoms of EAB, delimitation of infested areas)

Q24 Activities related to management and planning (e.g., management planning, ash tree inventories, tree removal or treatment)

Q10 In this section of the questionnaire we are interested in understanding how the emerald ash borer task force has influenced your work. Please think about your participation in EAB task force meetings, educational events put on by the EAB task force or in other interactions you feel are related to your involvement with the EAB task force. What have you come away with from participating.

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
My understanding of the ecological impacts of emerald ash borer has increased. (1)	❑	❑	❑	❑	❑
My understanding of the social and economic impacts of EAB have increased. (2)	❑	❑	❑	❑	❑

My understanding of the options and timeline for management of ash trees has increased. (3)	❑	❑	❑	❑	❑
A majority of my current knowledge about EAB comes from my involvement with the EAB task force process. (4)	❑	❑	❑	❑	❑
The EAB task force has helped me understand the perspective of others participating in the task force. (5)	❑	❑	❑	❑	❑
The EAB task force has become more important to my work over time. (6)	❑	❑	❑	❑	❑
My experience with the EAB task force process has led me to participate in new or surprising projects. (7)	❑	❑	❑	❑	❑
My views are similar to those of others involved in the EAB task force. (8)	❑	❑	❑	❑	❑
Over time, the process has changed my view on which goals should steer the management ash trees in the area. (9)	❑	❑	❑	❑	❑
My involvement has enhanced my cooperation with other individuals and groups/organizations that participate in the EAB task force. (10)	❑	❑	❑	❑	❑
My involvement enhanced my cooperation with other individuals and groups/organizations that don't directly participate in the EAB task force. (11)	❑	❑	❑	❑	❑
My involvement has enhanced my communication with other individuals and groups/organizations within the EAB task force. (12)	❑	❑	❑	❑	❑
My involvement has enhanced my communication with other individuals and groups/organizations outside the EAB task force. (13)	❑	❑	❑	❑	❑
I have collaborated with individuals I have met through the EAB task force on other projects. (14)	❑	❑	❑	❑	❑

Appendix II: Regression Tables

I calculated a mean for each task force of the normalized in-degree in the "prior" and in the "current" timeframe and the change (Table 3).

Table 3. Mean degree centralities by case. In-degree centrality values are normalized to group size to allow for comparison. New connections are measured by change in out-degree centrality between the two timeframes.

	Degree Centrality			
	Normalized IDC Prior	Normalized IDC Current	IDC Change	New Connections
Case 1	0.51	0.70*	0.19*	4
Case 2	0.48	0.84	0.36	9
Case 3	0.40	0.69*	0.30	8

* The numbers refer to the ratio of links to possible links within each task force prior to involvement, currently and the difference. Where values differed significantly from the mean based on a linear regression, they are marked with a star.

Regression Tables:

Change in in-degree centrality

Residuals:

```
    Min      1Q  Median      3Q     Max
-0.30134 -0.09859 -0.00298  0.09259  0.39509
```

Coefficients:

```
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                      0.36012    0.03177  11.337  < 2e-16 ***
regressionoutdegree$CaseUlster -0.16592    0.05023  -3.303  0.00157 **
regressionoutdegree$CaseWNY    -0.06382    0.04366  -1.462  0.14867
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.1556 on 64 degrees of freedom
Multiple R-squared:  0.1457,        Adjusted R-squared:  0.119
F-statistic: 5.459 on 2 and 64 DF,  p-value: 0.006474
```

Current in-degree centrality

```
Residuals:
    Min      1Q  Median      3Q     Max
-0.40774 -0.07812  0.02083  0.08934  0.29688

Coefficients:
                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                  0.83631    0.02706  30.906  < 2e-16 ***
regressionoutdegree$CaseUlster -0.13318    0.04279  -3.113 0.002769 **
regressionoutdegree$CaseWNY    -0.14495    0.03719  -3.898 0.000235 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1326 on 64 degrees of freedom
Multiple R-squared:  0.2138,    Adjusted R-squared:  0.1892
F-statistic:   8.7 on 2 and 64 DF,  p-value: 0.0004549
```